SSC SAN DIEGO

BIOSONAR PROGRAM

Hardware Implementation
&
Evaluation of Dolphin-based Biosonar Minehunting Principles

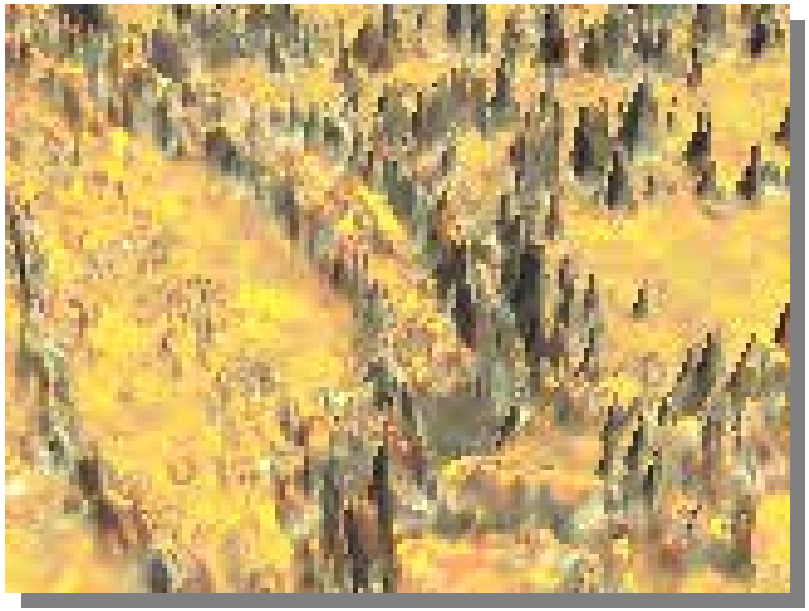
DARPA DSO
Dr. Alan S. Rudolph
Controlled Biological and Biomimetic Systems

SSC SAN DIEGO

Biomorphic Explorers

Biomorphic Communication & Navigation

- Includes novel techniques inspired by bees, bats, dolphins, etc.



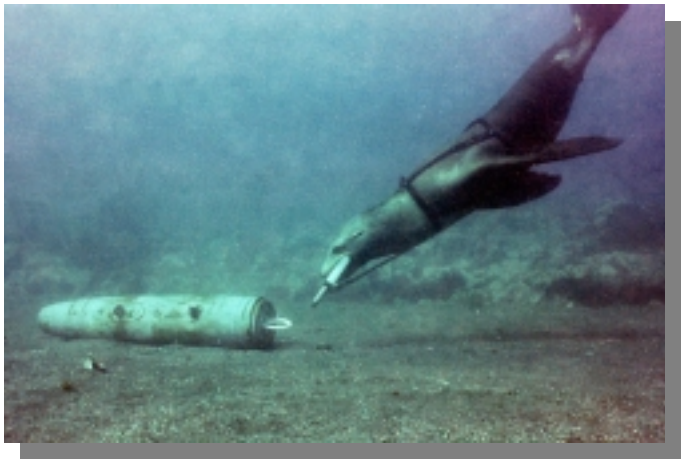
***The ocean*; Inner space- A vast part of our planet that remains virtually unexplored due to its harsh and uninviting environment.**

Mariana Trench

SSC SAN DIEGO

Marine Mammal Program

- Started in 1959
- Early research resulted in demonstrations of capabilities not available with hardware
- MMS systems developed and turned over to the Navy – MK 4, MK 5, MK 6 & MK7



SSC SAN DIEGO

SYSTEMS VIDEO

SSC SAN DIEGO

Marine Mammal Program

- **30 years of R & D**
  - **Initial efforts centered on capabilities**
  - **Organized /co-organized 6 international meetings on animal biosonar**
  - **Over 900 publications**
- **1984 Artificial Intelligence & bionics workshop, Stowe Vermont**

BIOSONAR MEETINGS

1996 – Frascati, Italy

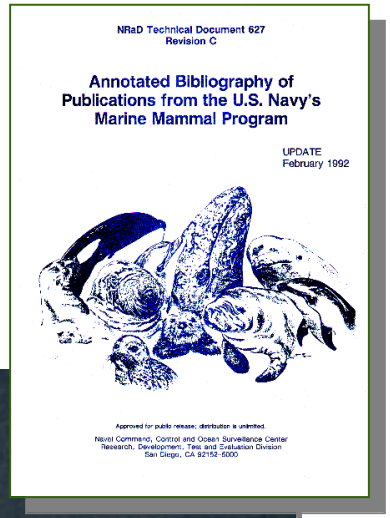
1979 – Jersey, Jersey Isles

1986 – Helsingor, Denmark

1991 – Moscow, Russia

1995 – SPAWARSYSCEN

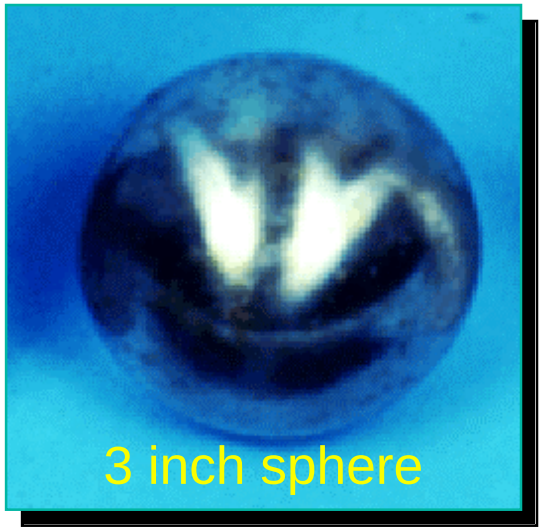
1998 – Carvoeiro, Portugal



SSC SAN DIEGO

DOLPHIN PERFORMANCE

- **DETECT 3” STAINLESS STEEL WATER-FILLED SPHERE AT 119m (-28dBTS)**
- **DETECT 0.2 mm WALL THICKNESS OF ALUMINUM CYLINDERS**
- **DISCRIMINATE MATERIAL**
  - **ALUMINUM**
  - **GLASS**
  - **ROCK**
  - **BRASS**
- **DISCRIMINATE SHAPE**
- **CLASSIFY TARGETS INDEPENDENT OF ASPECT**
- **DEMONSTRATE COGNITIVE SKILLS**



SSC SAN DIEGO

Biosonar Program Goals / Objectives

- Develop a biomimetic sonar that approaches the performance of MMS
  - **Metrics - P_D, P_{FA}, P_{CC} & search rate**
- Identify transition partner(s) for littoral applications in operational community
  - **PMS-EOD-3 VSW MCM autonomous underwater vehicle program**
  - **Biomimetic / robotic platforms**
  - **PEO USW - ASTO (submarine active sonar)**

DBS Sonar System

- **Two components: wet-end & dry-end**
- **ARL UT developing wet-end sonar set**
- **SSC SD developing dry-end & u/w trolley**
- **Sea tests at SSC SD**
- **SSC SD conduct algorithm assessments**

SSC SAN DIEGO

Experiments

- **ALTER Binaural Models (stationary)**
  - targets - simulators, distracters
  - target position and substrate fixed & known
  - grazing angle, depth, aspect, # of pings, range fixed & known
  - actual dolphin received echoes

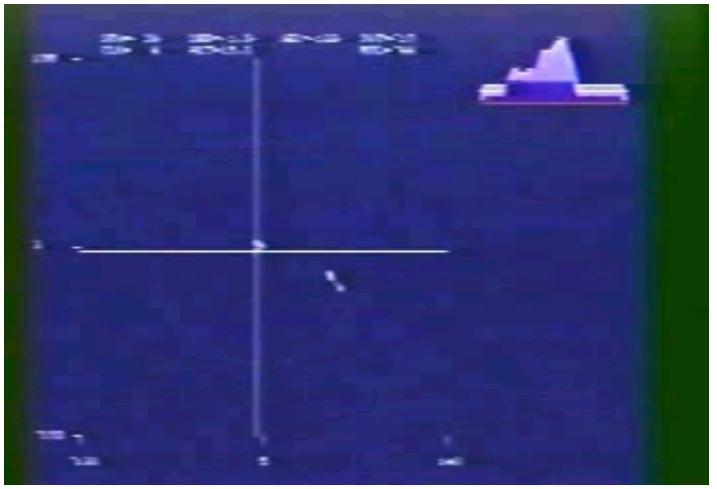
- **BMT Dolphin Benchmark (moving)**
  - **Target Position and Substrate Known**
  - **Waveform, Grazing Angle, Depth, Range, and Speed Selected by Dolphin, Quantified by BMT (Search Pattern)**
  - **Dolphin Received Echoes**

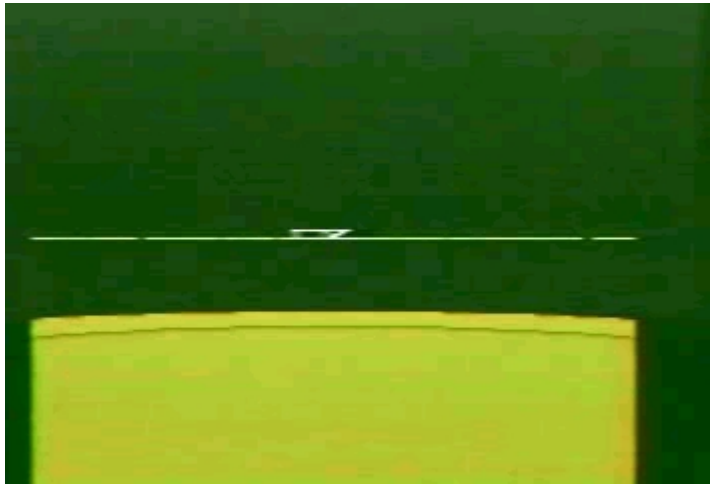
- **DBS Biosonar (moving)**
  - controlled testing of hypotheses from above & brassboard implementation
  - target position and substrate known
  - waveform, grazing angle, depth, range, and speed selected by sonar operator (research team)
  - comparison with dolphin on same minefields

SSC SAN DIEGO

Acoustic Response Monitor ARM

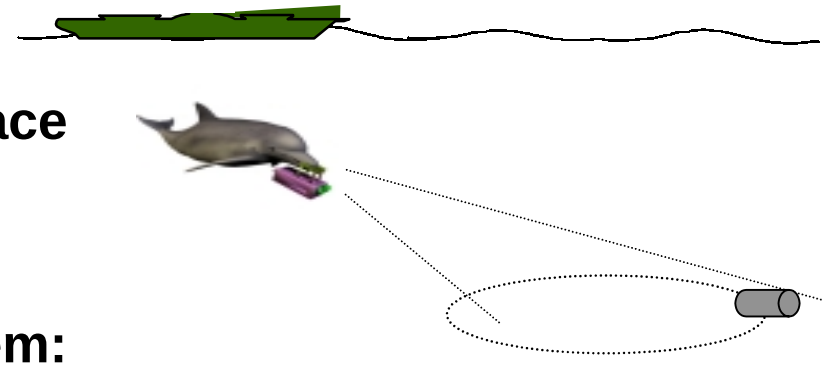
- First attempt to collect dynamic data
- Collected emitted signals for source analysis
- Required animal to remain at boat station
- Provided initial insight to signal modification





Biosonar Measurement Tool Concept

- **Instrumented Open ocean dolphin performing actual MCM task**
  - **20 ft. work boat with dolphin transport capability, DGPS surface nav., swim buoy, targets, onboard data upload computer**
  - **Bite-plate data acquisition system: emitted signal, biomimetic binaural receiver, dolphin head orientation & motion dynamics**



- **Laboratory analysis of dolphin strategy & data for Detect - Classify algorithms using VRML**

SSC SAN DIEGO

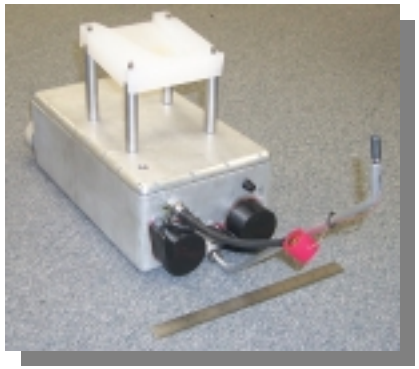
BMT Approach

- FY99: Design, develop, validate new data collection package
  - **Omni-directional outgoing biosonar click monitor hydrophone**
  - **Two directional hydrophones - model dolphins receiver**
  - **Underwater navigation system - passive inertial sensors (9DOF) and depth sensor.**
    - > **X,Y,Z magnetic/acceleration/angular rates**
    - > **Computed Heading, Pitch, Roll**
    - > **Independent depth sensor**
- Workboat DGPS/Computer system
- Instrumentation validation in laboratory

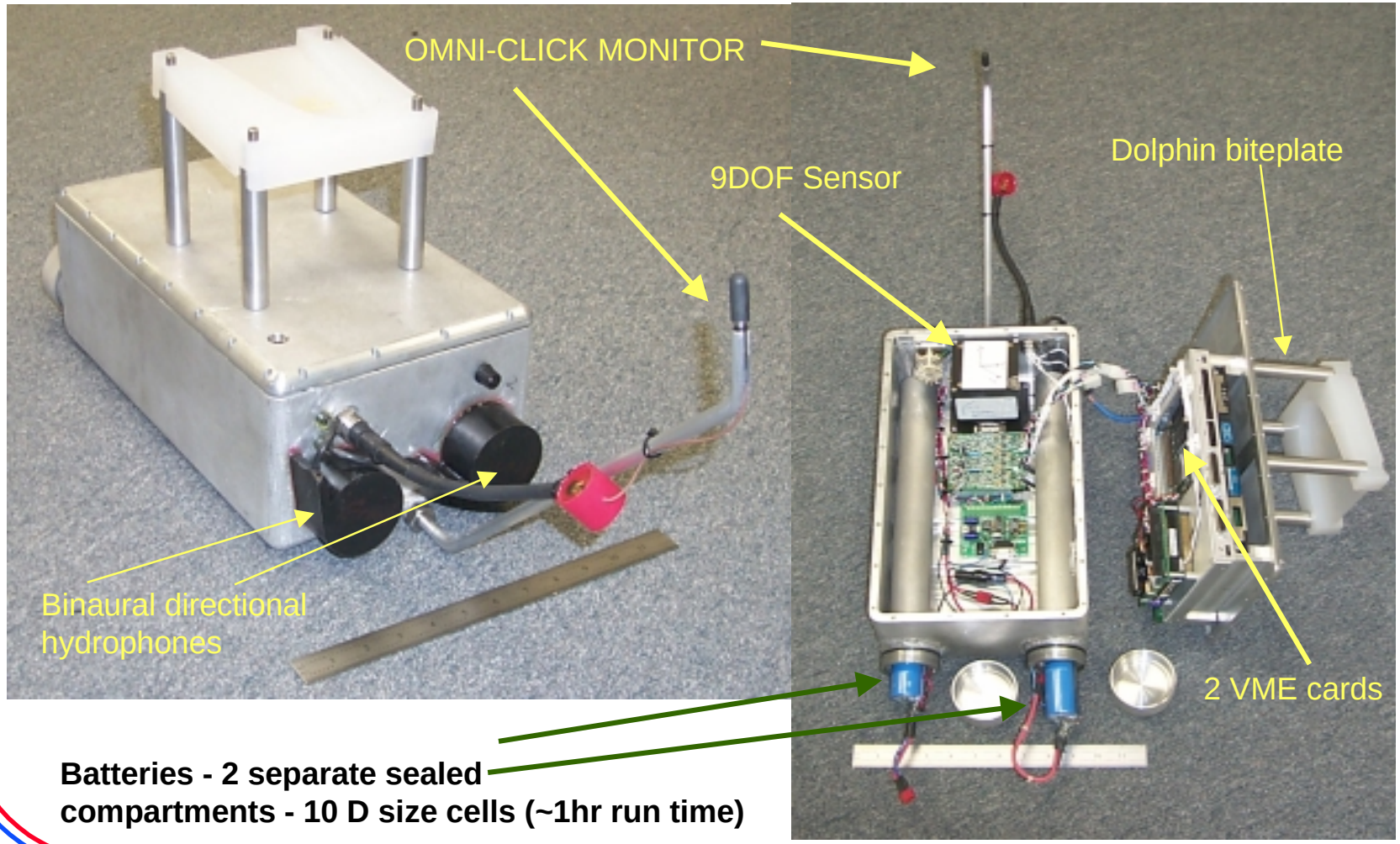
SSC SAN DIEGO

Biosonar Measurement Tool Overall Status

- **Two Dolphins are trained to carry bite-plate BMT - whistle when mine target detected.**
- **Boat DGPS/computer unit developed & installed**
- **Biteplate package operational in u/w housing**



BMT in U/W Pressure Housing

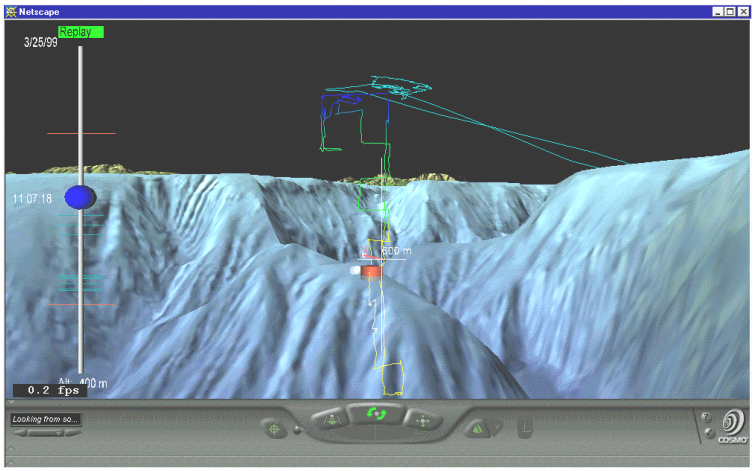


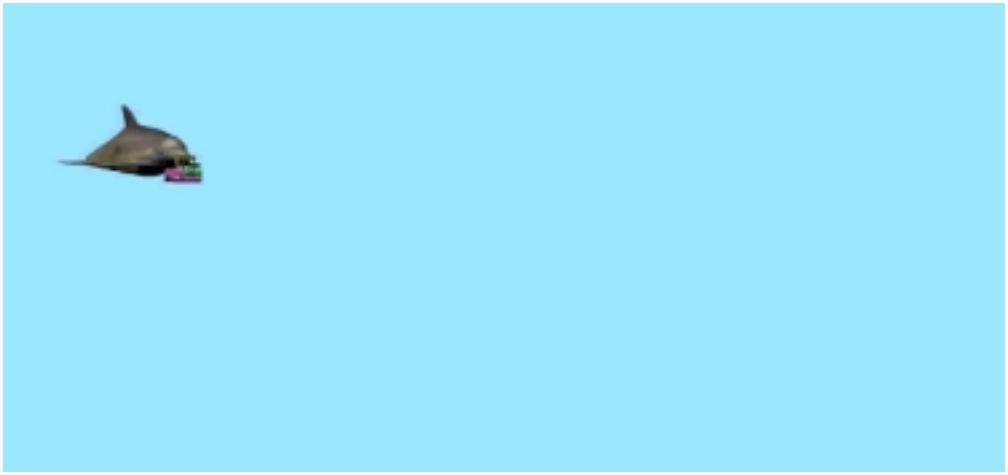
Batteries - 2 separate sealed compartments - 10 D size cells (~1hr run time)

SSC SAN DIEGO

Scientific Visualization

- Crucial to understand massive amounts of data as collect in this type of system
- Quickly review data runs, home in on interesting parts for detailed analysis
- Migrating to VRML / cooperation with Monterey Bay Aquarium Research Institute





SSC SAN DIEGO

BMT FOLLOW ON FY01

- **Analysis of Dolphin Biosonar minehunting strategies for buried targets**
  - **Instrument mine shapes**
  - **BMT mods - smaller, lower power, active acoustic navigation**
  - **Automate simulation/playback - VRML**
- **DARPA Biosonar Program**
  - **2 dolphins currently trained with BMT device**
  - **1-2 more dolphins to be trained**
  - **In-pen data collection begun & open ocean experiments with dolphins should begin in weeks.**

SSC SAN DIEGO

Summary

- Dolphin Based Sonar:
  - Truly broad band (BW > 80 kHz)
  - Biomimetic
  - Performance evaluated using Fleet metrics
  - Performance compared to Fleet assets
- Technology will produce significant advancement in Science and Technology domains
  - Littoral MCM
  - Broad band signal processing
  - Greater understanding of MMS
  - Biosonar capabilities